LIQUID CRYSTAL DISPLAY WITH A WIDE VIEWING ANGLE USING A COMPENSATION FILM

BACKGROUND OF THE INVENTION

(a) Field of the Invention

The present invention relates to a liquid crystal display having a wide viewing angle and using a compensation film.

(b) Description of the Related Art

Liquid crystal displays are typically structured including two substrates provided substantially in parallel with a predetermined gap therebetween, and liquid crystal material is injected between the opposing substrates. Each substrate includes an electrode. and an electric field is formed between the substrates by applying a voltage of a different potential to the electrodes. Accordingly, the alignment of liquid crystal molecules of the liquid crystal material changes to control the transmittance of incident light, thereby showing images.

Various types of liquid crystal displays have been developed to improve response times and viewing angle. They include the HAN (hybrid aligned nematic) mode liquid crystal display and the OCB (optically compensated bend) mode liquid crystal display. The OCB mode LCD is arranged symmetrically about an imaginary center plane between the two substrates and parallel to the same. That is, the liquid crystal molecules are aligned substantially parallel to the substrates, then are increasingly slanted until reaching this center plane where the liquid crystal molecules are substantially perpendicular to the two substrates. A wide viewing angle is achieved as a result. To obtain such a bent alignment of the liquid crystal molecules, a horizontal

orientation agent that is oriented in the same direction is used and a high voltage is initially applied. Also, the move of liquid crystal molecules in the same orientation when operating, realizes a wide viewing angle as well as fast response times.

However, since liquid crystal material has a birefringence where a refraction index of long axes of the liquid crystal molecules is different from that of short axes of the liquid crystal molecules, a different viewing angle may generate a different refraction index. Accordingly, the ratio of polarization becomes different when the linearly polarized light passes through the liquid crystals. Thus, the amount and color characteristics of the light vary depending on the viewing angle. Hence, color shifting, gray inversion and variations in a contrast ratio happen in the LCD as the viewing angle changes.

An OCB mode LCD is disclosed in U.S. Patent Nos. 5,410,422 and 5,805,253, in which a compensation film is used to compensate for a phase difference in liquid crystal cells. In these applications, a change in phase of light in liquid crystals is compensated in an opposite direction by the compensation film to solve the viewing angle problem. Here, a uniaxial or biaxial compensation film is used. In U.S. Patent No. 5,410,422, a retardation value of the uniaxial compensation film is limited to 60-85% of a retardation value of the liquid crystal cells, while a phase difference value of the biaxial compensation film of U.S. Patent No. 5,805,253 is limited to 0-100nm.

SUMMARY OF THE INVENTION

The present invention has been made in an effort to solve the above problems.

It is an object of the present invention to provide a liquid crystal display having a wide viewing angle that uses a compensation film, which minimizes color shifting and prevents gray inversion.

To achieve the above object, the present invention provides a liquid crystal display comprising a liquid crystal cell including a pair of transparent substrates with orientation layers deposited on inner surfaces thereof, and a liquid crystal layer realized through liquid crystal material injected between the substrates; biaxial compensation films provided on outer surfaces of the liquid crystal cell, the biaxial compensation films including an optical dielectric material layer; and polarization plates provided on outer surfaces of the biaxial compensation films, wherein if "d" is set as a cell gap of the liquid crystal cell, "R_{LC}" is set as a phase retardation value of the liquid crystal layer, an axis perpendicular to planes made by the substrates is set as a z-axis, x-axis and y-axis are formed on a planar surface of the substrates, and refractive indexes of molecules comprising the biaxial compensation films in the x, y and z directions are denoted by nx, ny and nz, retardation values (ny-nx)*d and (nz-nx)*d of the biaxial compensation films being respectively within ranges of -30 ± 5nm and $-R_{LC}/4 \pm 15$nm.

According to a feature of the present invention, liquid crystal molecules of the liquid crystal layer have a symmetrically bent alignment about an imaginary axis parallel and equidistant to the pair of substrates.

According to another feature of the present invention, the material layer of the biaxial compensation films is an optical dielectric material having a negative anisotropy.

According to yet another feature of the present invention, the liquid crystal display further comprises hybrid C plate compensation films provided between the liquid crystal cell and the biaxial compensation films.

In another aspect, the present invention provides a liquid crystal display comprising a liquid crystal cell including a pair of transparent substrates with orientation layers deposited on inner surfaces thereof, and a liquid crystal layer realized through liquid crystal material injected between the substrates; biaxial compensation films provided on at least one outer surface of the liquid crystal cell, the biaxial compensation films including an optical dielectric material layer; and polarization plates provided on outer surfaces of the biaxial compensation films, wherein if "d" is set as a cell gap of the liquid crystal cell, "R_{LC}" is set as a phase retardation value of the liquid crystal layer, an axis perpendicular to planes made by the substrates is set as a z-axis, x-axis and y-axis are formed on a planar surface of the substrates, and refractive indexes of molecules comprising the biaxial compensation films in the x, y and z directions are denoted by nx, ny and nz, retardation values (ny-nx)$*$d and (nz-nx)$*$d of the biaxial compensation films being respectively within ranges of -60 ± 10nm and $-R_{LC}/2\pm30$nm.

According to a feature of the present invention, liquid crystal molecules of the liquid crystal layer have a symmetrically bent alignment about an imaginary axis parallel and equidistant to the pair of substrates.

According to another feature of the present invention, the material layer of the biaxial compensation films is an optical dielectric material having a negative anisotropy.

According to yet another feature of the present invention, the liquid crystal display further comprises hybrid C plate compensation films provided between the liquid crystal cell and the biaxial compensation films.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate an embodiment of the invention, and, together with the description, serve to explain the principles of the invention:

FIG. 1 is a partial sectional view of a liquid crystal display having a bent alignment of liquid crystal molecules according to a preferred embodiment of the present invention; and

FIGs. 2, 3, 4A, 4B, 4C, 5, 6, 7, 8A, 8B, 8C, 9, 10, 11 and 12 describe viewing angle characteristics of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Preferred embodiments of the present invention will now be described in detail with reference to the accompanying drawings.

FIG. 1 shows a partial sectional view of a liquid crystal display having a bent alignment of liquid crystal molecules according to a preferred embodiment of the present invention.

As shown in the drawing, a liquid crystal display of the present invention includes a pair of opposing transparent insulating substrates 110 and 120; orientation layers 210 and 220 formed on inner surfaces of the substrates 110 and 120, respectively; a liquid crystal layer 320 formed of liquid crystal material injected between the substrates 110 and 120, the liquid crystal material being comprised of liquid crystal

molecules 310; hybrid C plate compensation films 410 and 420 formed on outer surfaces of the substrates 110 and 120, respectively; biaxial compensation films 510 and 520 provided on outer surfaces of the hybrid C plate compensation films 410 and 420, respectively; and polarization plates 610 and 620 provided on outer surfaces of the biaxial compensation films 510 and 520, respectively.

The liquid crystal layer 320 has a positive dielectric anisotropy. If a critical voltage is applied to the liquid crystal layer 320, the liquid crystal molecules 310 adjacent to the substrates 110 and 120 are aligned to a pretilt angle with respect to the substrates 110 and 120 as a result of properties of the liquid crystal molecules 310 and an orientation force of the orientation layers 210 and 220. Further, as approaching an imaginary plane, which is positioned parallel to the substrates 110 and 120 at a center thereof, the liquid crystal molecules 310 are increasingly bent by the decreasing influence of the orientation force and the increasing influence of an electric field vertical to the substrates 110 and 120. Accordingly, a symmetrical arrangement about the imaginary plane is formed by the liquid crystal molecules 310, resulting in two distinct regions. As a result of this alignment, a phase retardation of light passing through the liquid crystal layer 320 is compensated symmetrically about the imaginary plane such that a wide viewing angle is obtained.

The orientation layers 210 and 220 are horizontal orientation layers that provide an orientation force to the liquid crystal molecules 310 in a direction horizontal to the substrates 110 and 120. The orientation layers 210 and 220 undergo an orientation process such that they provide an orientation force in the same direction, thereby

obtaining the symmetrical arrangement of the liquid crystal molecules 310 about the imaginary plane.

The hybrid C plate compensation films 410 and 420 are made of a compound material having a negative dielectric anisotropy such as the WV film made by Fuji Film. The hybrid C plate compensation films 410 and 420 align short axes of molecules having a discotic molecule structure such that they have an increasingly larger angle with respect to a line normal to the substrates 110 and 120.

If an axis perpendicular to planes made by the substrates 110 and 120 is set as a z-axis, x-axis and y-axis are formed on a planar surface of the substrates 110 and 120, and refractive indexes of molecules comprising the compensation films 510 and 520 in the x, y and z directions are denoted by nx, ny and nz, the biaxial compensation films 510 and 520 are structured such that nx > ny > nz. Retardation values (ny-nx)∗d and (nz-nx)∗d of the biaxial compensation films 510 and 520 are respectively within ranges of -30 ± 5nm and $-R_{LC}/4\pm15$nm. And when only one of the two biaxial compensation films 510 and 520 is used, retardation values (ny-nx)∗d and (nz-nx)∗d are respectively in the ranges of -60 ± 10nm and $-R_{LC}/2\pm30$nm. This will be described in more detail hereinafter using results of an experiment as an example. Here, "d" refers to a cell gap of liquid crystal cells and "$-R_{LC}$" refers to a phase retardation value of the liquid crystal layer 320.

The polarization plates 610 and 620 act to polarize light only in the direction of a transmission axis of the polarizing plates 610 and 620. The transmission axis of the polarizing plates 610 and 620 can be either in a vertical or planar direction, with respect to the substrates 110 and 120.

FIGs. 2, 3, 4A, 4B, 4C, 5, 6, 7, 8A, 8B, 8C, 9, 10, 11 and 12 are views used to describe viewing angle characteristics of the present invention. In the drawings, Theta and Phi refer respectively to an azimuth angle and a polar angle. Also, CIE_{-x} and CIE_{-y} refer to positions of a bright state in the CIE1976 standard color chart. Luminance and Contrast in the drawings have their normal meanings, and θ_{max} refers to a maximum viewing angle.

In Experiments 1 through 3, the hybrid C plate compensation films 410 and 420 include a liquid crystal layer containing liquid crystal molecules having a discotic molecular structure and a negative anisotropic dielectric value, and a base film containing liquid crystal material. At this time, an angle made by the liquid crystal molecules from the body to an adjacent substrate 110 or 120 slowly increases from 4° to 68°. A direction to which an absolute value of a phase difference is at a minimum is a direction slanted 21° from a vertical surface of the base film. Here, a phase difference of the liquid crystal layer of the hybrid C plate compensation films 410 and 420 is 117nm, and a phase difference of the base film is 40nm. Further, a drive voltage used to display a bright state is 2V, while a drive voltage used to display a dark state is 6V.

<u>Experiment 1</u>

FIGs. 2, 3, 5, 6 and 7 show pictures of a dark state, bright state and contrast ratio of Experiment 1. FIGs. 4A, 4B and 4C illustrate a gray inversion of the Experiment of FIG. 3 according to angle variations with respect to a horizontal direction, vertical direction and a diagonal direction. FIGs. 8A, 8B and 8C illustrate a gray inversion of the

experiment of FIG. 5 according to angle variations with respect to a horizontal direction, vertical direction and a diagonal direction.

In Experiment 1, a dark state, a bright state and a contrast ratio are measured as a phase difference of the biaxial compensation films 510 and 520 (FIG. 1) is varied in the case where a liquid crystal cell gap is 6.0μm and a refractive index dielectric value of the liquid crystal layer 320 (FIG. 1) is 0.15.

FIG. 2 shows pictures of viewing angle characteristics when a planar phase difference (ny – nx)∗d of the biaxial compensation films 510 and 520 (FIG. 1) is -4μm and a phase difference (nz – nx) ∗d in a normal direction is -228μm. As shown in the drawing, in the dark state, light leaks a lot and a contrast ratio is measured less than 10 at a viewing angle of 80°.

FIG. 3 shows pictures of viewing angle characteristics when the planar phase difference (ny – nx)∗d of the biaxial compensation films 510 and 520 (FIG. 1) is -10μm and the phase difference (nz – nx) ∗d in a normal direction is -300μm. As shown in the drawing, in the bright state, light leaks a lot and a contrast ratio is measured less than 10 at a viewing angle of 80°. Further, with reference to FIG. 4A, it is evident from transmissivity measurements that gray inversion occurs.

FIG. 5 shows pictures of viewing angle characteristics when the planar phase difference (ny – nx)∗d of the biaxial compensation films 510 and 520 (FIG. 1) is -30μm at –30$\pm$5nm and the phase difference (nz – nx) ∗d in a normal direction is –228μm in the range of $-R_{LC}/4\pm15$nm. As shown in the drawing, the leakage of light in the dark and bright states is reduced, and a contrast ratio of greater than 20 is obtained at a

viewing angle of 80°. Further, with reference to FIG. 8A, it is evident that gray inversion does not occur.

FIGs. 6 and 7 show pictures of viewing angle characteristics when the planar phase difference (ny – nx)*d of the biaxial compensation films 510 and 520 (FIG. 1) is -30μm and the phase difference (nz – nx) *d in a normal direction is –218μm and –238μm. As shown in the drawings, the leakage of light in the dark and bright states is reduced when compared to FIGs. 2 and 3, and a contrast ratio of greater than 10 and 20 is obtained at a viewing angle of 80°.

Experiment 2

FIGs. 9 and 10 show pictures of a dark state, bright state and contrast ratio of Experiment 2. In Experiment 2, a dark state, a bright state and a contrast ratio are measured as the phase difference of the biaxial compensation films 510 and 520 (FIG. 1) is varied in the case where a liquid crystal cell gap is 6.0μm and a refractive index dielectric value of the liquid crystal layer 320 (FIG. 1) is 0.12. The hybrid C plate compensation films 410 and 420 (FIG. 1) are identical to Experiment 1.

FIG. 9 shows pictures of viewing angle characteristics in the case where the planar phase difference (ny – nx)*d of the biaxial compensation films 510 and 520 (FIG. 1) is -35μm at –30±5nm and the phase difference (nz – nx) *d in a normal direction is –180μm in the range of $-R_{LC}/4\pm15$nm. As shown in the drawing, the leakage of light in the dark and bright states is reduced, and a contrast ratio of greater than 20 is obtained at a viewing angle of 80°.

FIG. 10 shows pictures of viewing angle characteristics in the case where the planar phase difference (ny – nx)*d of the biaxial compensation films 510 and 520 (FIG.

1) is -35μm at –30±5nm and the phase difference (nz – nx) *d in a normal direction is –148μm in the range of $-R_{LC}/4\pm15$nm. As shown in the drawing, an extremely poor contrast ratio is obtained at a viewing angle of 80°.

Experiment 3

FIGs. 11 and 12 show pictures of a dark state, bright state and contrast ratio of Experiment 3. In Experiment 3, a dark state, a bright state and a contrast ratio are measured as the phase difference of the biaxial compensation films 510 and 520 (FIG. 1) varies when a liquid crystal cell gap is 6.0μm and a refractive index dielectric value of the liquid crystal layer 320 (FIG. 1) is 0.167. The hybrid C plate compensation films 410 and 420 (FIG. 1) are identical to Experiments 1 and 2.

FIGs. 11 and 12 show pictures of viewing angle characteristics in the case where the planar phase difference (ny – nx)*d of the biaxial compensation films 510 and 520 (FIG. 1) is -30μm at –30±5nm and the phase difference (nz – nx) *d in a normal direction is –255μm and –265μm in the range of $-R_{LC}/4\pm15$nm. As shown in the drawings, the leakage of light in the dark and bright states is reduced, and a contrast ratio of greater than 10 and 20 is obtained at a viewing angle of 80°.

In the liquid crystal display of the present invention described above, with the use of the biaxial compensation films of a planar phase difference (ny – nx)*d in the range of –60±10nm and a phase difference (nz – nx) *d in a normal direction in the range of $-R_{LC}/2\pm30$nm, a wide viewing angle and a high contrast ratio are obtained. Further, color shifting is minimized and gray inversion is prevented.

Although preferred embodiments of the present invention have been described in detail hereinabove, it should be clearly understood that many variations and/or modifications of the basic inventive concepts herein taught which may appear to those skilled in the present art will still fall within the spirit and scope of the present invention, as defined in the appended claims.